4.5 Is It Safe? Overview of an Integrated Research Program in Support of the Long-Term Stewardship of the DOE Complex

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Abstract

Over the past seven years, through DOE support, the Center for Bioenvironmental Research (CBR) has developed a natural laboratory for development of new biosensor and biomarker technologies and a program for risk evaluation and communication. In addition, the CBR is conducting research on receptor-based methods, such as endocrine disruption, for assessments of how environmental "signals" affect long-term human, ecological, and ecosystem health. The CBR has leveraged these capacities into an integrated program focusing on 1) development of long-term risk assessment models for contaminant mixtures at selected DOE sites, 2) food-web modeling, 3) ecological biomarker sentinels for contaminant exposure, 4) biosensor technology development, 5) environmental informatics and geographic information systems, and 6) risk communication with a special focus on Native American tribes and other underserved populations. The CBR's goal is to effectively position the DOE as a leader in the complex emerging field of environmental signaling and provide the DOE with the power to harness this knowledge and provide new solutions to DOE Long-term Stewardship (LTS) concerns. The CBR is integrating its program with complementary initiatives at DOE laboratories and other research consortiums to ensure that the DOE's LTS program achieves its promise and overcomes its challenges throughout the next centuries.

DOE-NETL/CBR Cooperative Agreement: Is it Safe? An Integrated Approach in Support of Long-Term Stewardship of DOE Complex

Summary Report

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ABSTRACT

The Center for Bioenvironmental Research (CBR) at Tulane and Xavier Universities in New Orleans, Louisiana has entered into a cooperative agreement with the U.S. Department of Energy's Environmental Management (DOE-EM) Program entitled "Is It Safe? An Integrated Research Program in Support of the Long-Term Stewardship of the DOE Complex" (DE-FC26-00NT40843) for the period 9/29/00 through 9/28/03. One of the primary tasks associated with this cooperative agreement is that the CBR will help facilitate the development of a research "agenda" for long-term stewardship. This report summarizes the activities employed to date that support this task and includes discussion of how these activities are compatible with other entities involved in the Long-Term Stewardship program.

I. Introduction

A. CBR: The DOE Hub for Environmental "Signaling"

In order to develop a successful Long-Term Stewardship Program, the DOE must ensure that all entities participating in this program fit into an integrated framework for research, communication, and technology development. Over the past seven years, through DOE support, the CBR has developed a unique natural laboratory for development of new biosensor and biomarker technologies and a program for risk evaluation and communication. In addition, the CBR is world-renowned for its expertise in development of receptor-based methods, such as endocrine disruption, for assessments of environmental "signals" affecting human, ecological, and ecosystem health. As its contribution to the DOE's Long-Term Stewardship research agenda, the CBR is leveraging this capacity into an integrated program focusing on the following four themes: 1) risk assessments based on environmental signaling, 2) biosensor technology development, 3) environmental informatics and geographic information systems, and 4) risk communication with a special focus on Native American tribes and other underserved populations. The CBR's goal is to effectively position the DOE as a leader in the complex emerging field of environmental signaling.

The CBR's intent is to continually build upon its past accomplishments and provide for the long-term application of this research on systems of relevance to the DOE. This integrated program of basic and applied research, technology development, and technology transfer will:
Provide models to exemplify how the clean-up/technology development process can be guided through ecological and risk analyses.
Undertake a research program for the development of new receptor based technologies related to hazard monitoring that will provide more cost-effective solutions to environmental restoration and waste management problems facing the DOE complex.

Provide a better understanding of the problems associated with contaminated aquatic systems, including endocrine disruption, thereby providing new insights that will lead to the development and use of highly innovative technologies to assess risk, to perform environmental monitoring, and to be used in environmental clean-up.
Provide models for building capacity and assessing risk perceptions of tribal and underserved populations of concern to the DOE.

The CBR has been pioneering research in the new area of environmental signaling for the past five years through complementary funding from the DOE, Department of Defense (DOD), USDA, National Institutes of Health (NIH), and other federal, foundation, and private sources. Studies are being pursued that focus on the way that:

- contaminants move through the environment,
- they interact with receptors that regulate cellular functions, and
- these receptors can be used as the basis of new technologies for hazard monitoring and remediation.

The use of receptor-based methods to perform hazard monitoring has novel advantages compared to traditional methods that are used in ecological and human health risk assessment. Receptor based studies provide not only direct information about changes in molecular biomarkers used to measure exposure to contaminants, but also information about endocrine disrupting effects of specific contaminants.

Environmental exposure to endocrine disruptors is currently an area of intense worldwide interest. The National Research Council and the National Academy of Sciences have declared this area of research a national priority. A White House Task Force conducted an inventory of all federally funded endocrine-disruptor related research providing a research baseline and identifying data gaps. The White House also established an Interagency Task Force to respond to the national need for understanding both the short and long-term influences that endocrine disrupters can have on the ecosystem and human health. Congress has passed a bipartisan amendment to the Clean Air and Water Act to provide funding for studying endocrine disruption. A grant awarded to the CBR and work being carried out at Oak Ridge National Laboratory by CBR collaborators are among the few, and perhaps only, projects in the area of endocrine disruption that are currently in the DOE's research portfolio.

B. CBR in the Context of DOE's Long-Term Stewardship Program

As a collective framework of research, educational, and administrative activities, the CBR's "agenda" is evolving through time to complement the evolving needs of DOE programs. As such, the CBR is conducting and participating in informational workshops at DOE and other international workshops throughout

the project period to facilitate development of an effective research agenda. The CBR is developing, and document, a better understanding of what the limitations and uncertainties of its findings for sound application to DOE's long-term needs. Finally, the CBR's communication activities are consistent with that agenda. The activities are coordinated with and conducted in collaboration with other organizations that are involved with various aspects of the DOE's long-term stewardship activities. This includes: the Idaho National Engineering and Environmental laboratory, the Institute for Responsible Management, DOE site contractors, other National Laboratories and the EM Focus Area Teams.

In order to ensure compatibility, the CBR's LTS Program fits within the framework of the DOE's overall mission to maintain and continuously improve protection of public health, safety, and the environment at a site or portion of a site assigned to DOE for such purposes. This mission includes providing sustained human and environmental well-being through the mitigation of residual risks and the conservation of the site's natural, ecological, and cultural resources. Mission activities will include vigilantly maintaining "post-cleanup" controls on residual hazards; sustaining and maintaining engineered controls, infrastructure, and institutional controls; seeking to avoid or minimize the creation of additional "post-cleanup" long-term stewardship liabilities during current and future site operations; enabling the best land use and resource conservation within the constraints of current and future contamination; and periodic re-evaluation of priorities and strategies in response to changes in knowledge, science, technology, site conditions, or regional setting. The [LTS] will coordinate activities to identify and promote additional research and development efforts needed to ensure this protection and to incorporate new science and technology developments (Figure 1) that result in increased protection of human health and the environment and lower costs.

Through consultation with the DOE during the first year of this program, the CBR is focusing on facilities within the DOE Complex including Hanford, Oak Ridge, SRS, Brookhaven, and Rocky Flats. Already, specific research projects within the task areas of this project have developed into usable technologies for DOE and other government and private entities including novel approaches using receptor-based methods and environmental signaling for sensor and bioremediation technology development.

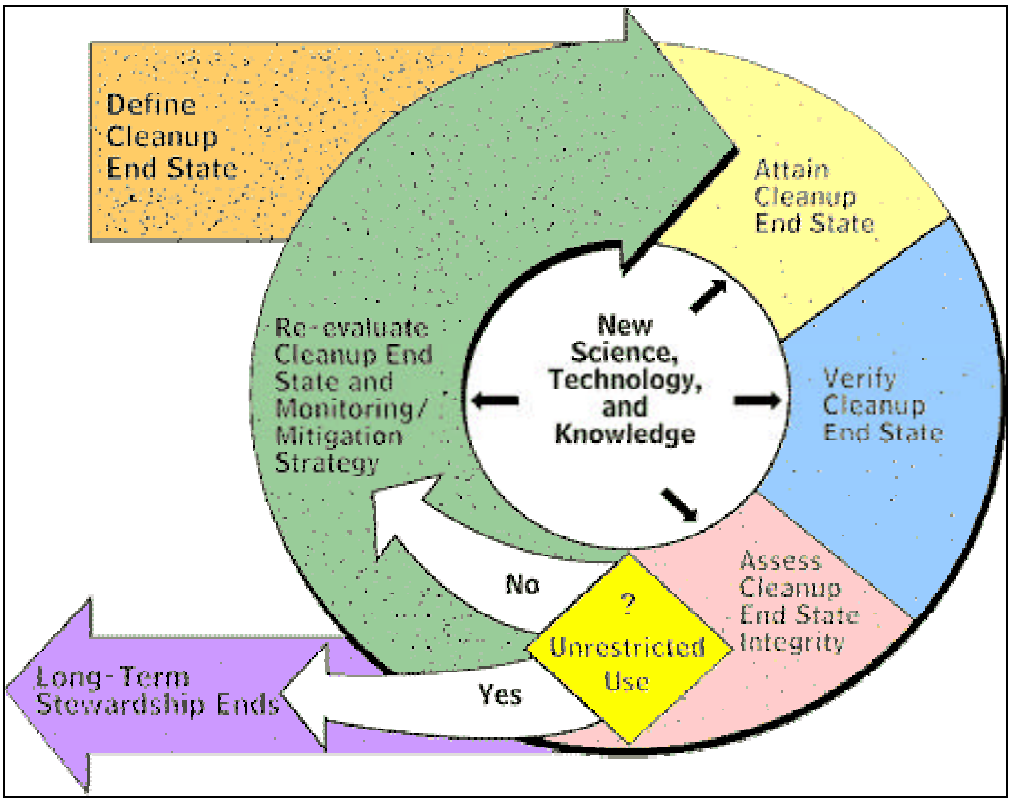

Figure 1. Framework for U.S. Department of Energy (DOE) Long-Term Stewardship Process (http://lts.apps.em.doe.gov/mission.asp)

The use of receptor-based methods, such as endocrine disruption, to perform hazard monitoring has novel advantages compared to traditional methods used for ecological and human health risk assessment. Leveraging upon the CBR's experience with its model ecosystem and its internationally renowned expertise on environmental signaling the CBR will collaborate with the DOE's national labs consistent with its scope of work. In addition, the CBR will continue to develop innovative technologies and transfer them through cooperative programs to the DOE and other government and commercial sectors.

II. CBR's Year 1 Research Activities

Summarized below are the research activities employed by CBR during the first year of its Long-term Stewardship cooperative agreement as part of its contribution to DOE's collective research framework. For more detail on specific objectives, tasks, deliverables and timelines related to these projects, please refer to the quarterly reports provided as part of this cooperative agreement (available upon request).

Research activities have been organized in the context of the CBR's scope of work (SOW) summarized previously and include the following:

A. Research Agenda Development
B. Basic and Applied Research for Technology Development

C. Risk Analyses, and
D. Social Science Research and Risk Communication and Coordination

A. Research Agenda Development

Many of the activities associated with development of a research agenda are not of an experimental nature. Rather, these activities consist of workshops, development of research and communication activities, and coordination with other organizations that are involved with various aspects of the DOE's long-term stewardship activities. These activities are included in CBR's quarterly report submissions.

B. Basic and Applied Research for Technology Development

CBR's basic and applied research for this program employs a variety of activities including fate and transport, human and ecological biomarkers of exposure and toxicity, and biosensor and other technology development.

1) Fate and Transport and Analytical Methods for Detection of Contaminants

Lead (Pb) Isotopes in Bayou Trepagnier Sediments

This project is investigating the transport, uptake and fate of Pb in natural ecosystems using Pb isotopes as tracers in Bayou Trepagnier, Louisiana. The different sources of pollutant Pb transported to the bayou ***through time*** will be identified and their proportions estimated. The objective is to analyze the Pb isotopic composition of samples in four well-dated sediment cores from the contaminated Bayou Trepagnier area. The variation of the contaminant-Pb isotopic composition through time will be determined. Given the Pb isotopic composition of potential contaminant end members, Pb mass balances over the past 60-70 years will be estimated. Subsamples from this work will be utilized for development of new analytical methods for monitoring of polycyclic aromatic hydrocarbons (PAH's).

2) Biomarkers of Exposure and Toxicity

Flavones as P450 1A2 Inhibitors

Cytochrome P450 enzymes are a superfamily of proteins that metabolize (e.g., for excretion) a wide variety of compounds such as drugs, natural products, pesticides, carcinogens, and other environmental chemicals, as well as endogenous compounds such as prostoglandins, fatty acids, and steroids. Human P450 1A2 is involved in the metabolism of a number of important drugs

and environmental chemicals such as caffeine, acetaminophen, cigarette smoke components, and estradiol. Several flavones, a class of phytochemical compounds, have been shown to inhibit the P450 1A2-dependent demethylation of methoxyresorufin, in an ***in vitro*** assay of this specific enzyme's activity. This study will expand on this model and apply this knowledge to compounds and contaminants of concern at DOE sites so that assessments of relative impacts of natural vs. synthetic compounds can be performed.

The Dragonfly: A New and More Effective Biomarker of Pollution

Currently, there is no insect biomarker model, even though insects play key roles in most terrestrial ecosystems. Most pollutants and toxicants occur at the highest concentrations in the soil or sediment due to solubility and diffusion; however most current biomarker species spend little or no time in these areas. The development of a biomarker species that resides a significant portion of its lifespan in the sediment may prove to be a more sensitive indicator of environmental health and stability. Dragonflies are an excellent example of an insect species that spends one or more years in the sediment. The main goal of this study is to develop a new and more effective biomarker species of pollution: the dragonfly. This new biomarker species will then be used to measure environment health at DOE sites, polluted sites, and clean (toxicant-free) sites.

In order to apply this research to DOE's needs, the CBR will compare and contrast the genetic structure of populations of a common dragonfly species, the green pondhawk (***Erythemis simplicicollis***), from selected DOE sites, "polluted" sites (e.g. heavy metals, petroleum), and "clean" sites (e.g. toxicant-free). It is hypothesized that differences will be detected in the genetic structure of the stressed and unstressed populations, due to the differential survival of individuals with different genotypes. So, for example, when a population is identified with a very low frequency of allele B or where B is absent, that population or environment may have been exposed to heavy metals and should be examined closer in order to assess long-term impacts of this component of ecological health.

3) Biosensor and Other Technology Development

Detection of Estradiol and Estrone in Aqueous Environments

A continuous flow immunosensor (antibody-based biosensor) has been developed that permits low ppb (ng/ml) detection for a wide range of small molecular weight compounds, including drugs, explosives, and pesticides in a variety of water matrices. It was proposed to use this instrument for the development of an assay for the detection of estradiol and estrone. Antibodies against estradiol and estrone have been routinely used in radioimmunoassays for the detection of these two compounds.

Previously in our laboratory, a Cy5 fluorescent-estradiol conjugate has been synthesized. This fluorescent conjugate and commercially available antibodies will be employed to develop a displacement assay (biosensor) that is specific for estradiol and estrone. Initial tests will be aimed at selecting the best antibody-fluorescent antigen pair for the displacement assay. After the flow and buffer conditions are optimized, we plan to spike samples to determine levels of detection and specificity. Next, we will analyze environmental water samples (groundwater, sewage treatment waste water and seawater) that are known to be contaminated with estradiol and estrone. A direct comparison of the results from the continuous flow immunosensor with standard methods of estradiol and estrone detection will be made on all test water.

Development of Zeolite Membranes for Remediation of Radioactive Effluents

The objective of this project is to synthesize ion selective membranes on porous supports for chemical remediation of radioactive species from wastewater. The vapor transport method instead of traditional hydrothermal method will be used to prepare zeolite membranes for ultimate application to DOE's remediation needs.

C. Risk Analyses

1) Aquatic Biomarker Assessments for Risk Assessment

The investigators in this project are conducting exposure assessment and developmental toxicity studies for pollutants at DOE sites using a laboratory fish biomedical and ecological model, Japanese medaka embryos. Evaluation of resources needed to initiate this project within existing laboratory research utilizing the medaka fish colony are in progress. The chemical(s) for this laboratory research were selected (in coordination with DOE) during the third quarter and experimental protocols focusing on developmental toxicity are being prepared. Future research will include food enhanced web modeling initiated during the third quarter for relevant wildlife species for ecological risk assessment and will be coordinated with geographic information systems (GIS) applications described below.

2) Geographic Information Systems

The above research will be synthesized for incorporation in overall frameworks for ecosystem health to aid the DOE in natural resource damage assessments through Geographic Information Systems (GIS) applications. There is interest on the part of DOE and the IMC to explore the use of GIS and remote sensing (RS) toward understanding the potential impacts of contaminants (including potential endocrine-disrupting chemicals, or E-DCs) at or near certain DOE sites.

Additionally, interest has been expressed in developing GIS datasets relating to a prototype for watershed analysis at Rocky Flats or other DOE site , as well as those relating to the Nuclear Regulatory Commission's Decommissioning Standard Review Plan. DOE officials visited the Recipient's facilities at Tulane University to discuss these issues on March 15, 2001. Specific GIS-related requirements have been laid out during this meeting. This deliverable will provide only general GIS-database structure and analysis details; we will document all new requirements and structures in the next quarterly report. Assuming that the IMC would pursue an assessment of hazard, vulnerability, and/or risk relating to potential endocrine-disrupting chemicals, the following datasets (spatial and/or tabular) would be necessary for the construction of an integrated GIS database and for the analysis of the potential impacts of these chemicals:

- Delineation of watershed around highest concentration of sites at which E-DCs were released in largest quantities and at most recent times.
- Digital elevation models (DEM), depending on the size of the watershed and the nature of the study.
- Soils data (class, texture, permeability, etc.), either from the Natural Resource Conservation Service or other source, including soil samples from the field.
- Remotely sensed imagery (e.g., multispectral and/or hyperspectral). Surface and subsurface geology datasets, stored as attributed vector polygon data in Arc coverage format.
- Hydrology (stream network) datasets.
- Transportation datasets.
- Demographic datasets.
- Project-specific datasets. These will be determined by the DOE's direction as to project goals, and may include locations of health-related cases, locations of known contamination/release points, wells, pipelines, holding ponds, jurisdictional boundaries, etc. These datasets would mostly be stored as point, line, and polygon vector data in Arc coverage format.

D. Social Science Research and Risk Communication and Coordination

1) Tribal Capacity Building

CBR efforts were initiated to begin the planning of several capacity building activities that will involve primarily those tribes with on-going relationships with the DOE EM program. The intent of these activities is to help build the capacity of tribes to enable them to address DOE-related issues.

A Tribal Radiological Emergency Preparedness (TREP) Workshop was held in March, 2001, in Phoenix, Arizona. Approximately 20 participants were involved in the equivalent of a 40-hour Hazardous Materials (HazMat) training course in

which participants earned 12 hours credit and a certificate for HazMat Training from the Illinois Fire Institute at the University of Illinois (which approved the curriculum used at the workshop). The goal of the workshop is to provide training to tribal emergency first responders on topics ranging from basic hazardous materials labeling and packaging to planning and responding to emergency spills and accidents. Coordinating efforts with county and state officials is emphasized in the course as well as use of proper communications protocol, with a mock drill exercise scheduled with a local Fire Department. The workshop is co-sponsored by the National Congress of American Indians (NCAI) and partially funded by the US DOE Office of Civilian and Radioactive Waste Management. In addition, the TREP workshop is designed to address tribal government regulatory, cultural and jurisdictional considerations relevant to transportation of hazardous waste. Tribal planning and guidance documents have been developed specifically for TREP training.

An Air Monitoring Workshop was conducted in New Orleans on April 10-12, 2001. Approximately 50 individuals participate. The workshop is partially funded by US EPA and co-sponsored by the Institute for Tribal Environmental Professionals at Northern Arizona University (a Hispanic-Serving Institution).

2) Documenting Tribal Concerns

Xavier's Center for Environmental Prog rams continued to update the **Documented Concerns Database**. Initiated in 1994, the Database contains at least 5,000 documents on Hanford citizens expressing their opinions regarding activities at the DOE Hanford installation. In addition to the Hanford data, the Database also contains citizens' concerns associated with activities at INEEL, Rocky Flats, Oak Ridge, Fernald and SRS. More recently, CBR's Information Management Core (IMC) is integrating the Database with DOE's Central Internet Database (CID). Another effort is to migrate the CERE Documented Concerns Database into an on-line database information system creating ***a mature and robust decision-support database environment consistent with the DOE CID model.*** This system will cross-reference the information contained in the DOE CID and public opinion to develop a useful Decision-Support Database Architecture. For more information on the migration effort, please refer to the CBR's Topical Report on the IMC's database structures.

3) Office of Environmental Affairs

The Office of Environmental Affairs (OEA) is developing ways of teaching principles and practices of long-term stewardship by involving Tulane University students, staff and faculty in the assessment and amelioration of the university's environmental impacts. The OEA seeks to make long-term stewardship "everyday"— a part of decision-making and action in every program and position across the university. Tulane is in the first phases of implementation of an ISO 14000 Environmental Management System. As the university shares many

operational features with government facilities, businesses and other institutions, it is an ideal laboratory for developing educational and management programs in long-term stewardship. Because of its centrality to long-term stewardship, global climate change in relationship to facility operations and associated energy consumption was selected as a focus of research.

III. CBR Year 2 Research Proposed Projects and Cores

For the second year of its cooperative agreement, the CBR has proposed to continue the first year projects described above and augment this suite with two additional projects: one to develop a biosensor for measuring mercury in fish tissue and a second to look at long-term failure of containment liners on chemical diffusion. These projects and research cores are summarized in Table 1.

Table 1. Summary of Year 2 Proposed Research Project and Cores

Project Name	Investigator
Tulane Research Projects	
Risk Assessment Research Core · Risk assessments for Tritium and other selected metals and organics · Food-web modeling	Abdelghani, Assaf (EHS) Hartley, William (EHS) Thiyagarajah, Rani (EHS) Watanabe, Karen (EHS)
Pb Isotopes in Lake Pontchartrain sediments: fingerprinting history of poll'n	Marcantonio, Franco (Geology)
Rapid, antibody-based detection of Mercury and Methylmercury in fish tissues	Blake, Diane (Ophtamology)
Effect of deformation on permeation through geomembranes	DeKee, Daniel (Chemical Engineering)
Development of new models for estrogenic signaling.	Ma, Liang (MCB)
Environmental Studies and Envirronmental Office · Student environmental research and education projects · Energy efficiency programs	Zimmerman, Michael (Philosophy) Davey, Elizabeth (Office of Env. Affairs)
Xavier Research Projects	
Risk Communication Program · Tribal and Radiological Emergency Preparedness (TREP) Workshops · Air Monitoring Workshops · Documenting tribal concerns with real-time web access · Native American tribal GIS training	O'Connor, Sally (CEP, Chemistry)
Flavones as P4501A2 Inhibitors	Foroozesh, Maryam (Chemistry)
Investigating the fate and transport of PAHs and heavy metals in soils and sediments from DOE operations sites	Wang, Guangdi (Chemistry) Mielke, Howard (Pharmacy)
The Dragonfly: A new and more effective biomarker species of aquatic pollution	Schlueter, Mark (Biology)
Development of zeolite membranes for remediation of radioactive wastes	Zhang, Jian (Chemistry)
Program Support Cores	
Information Management Core · GIS research and support · Database management · Web-based information access · Demographic analyses surrounding DOE sites · Native American tribe GIS training	Meffert, Douglas
Morphometrics/ Environmental Signals Core · Environmental hormone impacts on humans · Environmental hormone impacts on animals · Development of risk frameworks across species and chemicals	McLachlan, John
Research Communication Core · 2002 New Orleans International Stewardship Symposium · Development of science & technology LTS communication strategies for DOE target audiences · Reporting · Educational outreach	Wilson, Valerie

IV. Conclusion

The information provided in this report is not deemed by the CBR as exhaustive of its efforts and contributions towards the DOE's LTS Research Agenda. It is a living program that will evolve as the projects described above mature and as the CBR continually increases its interactions with the DOE and its affiliates that are involved in developing this crucial framework. Through novel approaches using receptor-based methods, environmental signaling, and exploitation of natural remediation processes, the CBR has provided the DOE with the power to harness this knowledge and provide new solutions to DOE concerns. Through execution of the projects described above, maturing coordination and collaboration with other LTS researchers and communicators, and encouragement of new science and technological perspectives and applications to LTS, the CBR will help ensure that the DOE's LTS program evolves to meet its challenges throughout the next centuries.

LIST OF ACRONYMS AND ABBREVIATIONS

CBR	Center for Bioenvironmental Research
CEP	Center for Environmental Programs
CERE	Consortium for Environmental Risk Evaluation
CID	Central Internet Database
DOD	U.S. Department of Defense
DOE-EM	U.S. Department of Energy Environmental Management
E-DCs	Endocrine-Disrupting Chemicals
EIL	Environmental Informatics Lab
GIS	Geographical Information Systems
HazMat	Hazardous Materials
IMC	Information Management Core
INEEL	Idaho National Engineering and Environmental Laboratory
IRM	Institute for Responsible Management
LTS	Long-Term Stewardship
NCAI	National Congress of American Indians
NETL	National Energy Technology Center
NIH	National Institutes of Health
OEA	Office of Environmental Affairs
ORNL	Oak Ridge National Laboratory
PAH	Polycyclic Aromatic Hydrocarbon
Pb	Lead
RS	Remote Sensing
SOW	Statement of Work
TREP	Tribal Radiological Emergency Preparedness
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency